

Organic Potato Product for Baby Foods and Dietetic Food

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Abstract

The article indicates the relevance of producing organic potato, primarily for children who need special protection from damage caused by pesticides, nitrates and Heavy Metals (HM), as well as for medical nutritional therapy of people suffering from chronic diseases. We have identified tasks and purposes for studying the dynamics and intensity of pesticide accumulation in the potato tubers; revealing the effectiveness of biological insecticides; determining heavy metal contamination level of products near anthropogenic area – the M-4 'Don' federal highway; revealing nitrate accumulation in the tubers at different fertilizer doses; determining duration of various hazardous components accumulated in potato tubers and giving production recommendations for safety interval between pesticide application and harvesting operations. Field experiments were conducted at Educational and Experimental Farm of Bunin Yelets State University. Chemical insecticide Actara and biological agents Fitoverm, Acarin, Bitoxybacillin were used for pest control. Antifungals (fungus killers) Profit Gold (TANOS) and Ridomil Gold and herbicides (weed killers) Sencor and Rimus were also applied. Sencor and Rimus remained in potato tubers longer, for 55 and 66 days after processing, respectively. Nitrate threshold limit value (80 mg/kg) was not exceeded in the experiments with NPK composition options: N30-60P60-90K30-60. Accumulation of heavy metals in tubers increased at a distance of 50m from the highway, but did not exceed TLV. At 100 meters away from the road HM were detected in the tubers, but in smaller concentrations. Lead and cadmium were not discovered in potato tubers grown at a distance 500 meters away from the highway.

Keywords: Heavy Metals, Nitrates, Organic Products, Pesticides, Potato

1. Introduction

The problem of producing ecologically pure potatoes suitable for children and dietary nutrition in conditions of the Central Black Earth Region of Russia is very urgent and requires measures to be taken. Among the factors which worsen the quality of potato production special attention is drawn to the content of pesticide residues, Heavy Metals (HM), elevated nitrate concentration. The situation is aggravated by the fact that exactly for baby and dietary nutrition potato is not cultivated in the region. On the one hand, this is related to the absence of proper certification and pricing policy in relation to the production of organic potato products in the country. On the other hand, this occurs due to the lack of clear agronomic recommendations on cultivation of such products. Therefore, individual farmers as well as large

agricultural companies engaged in cultivation of food potatoes have no interest in incurring costs and producing organic product. As a result, children's hospitals and health care centers are provided with ordinary potato which does not meet the medical nutritional therapy requirements.

Scientific novelty of our work is as follows: conditions, factors and level of the toxic substance contamination of food potato have been studied in detail for the first time in the Central Black Earth Region, and cultivation techniques have been developed which allow getting the organic products for baby and dietary nutrition.

In this regard, the purpose of our research was:

- To study the dynamics, the intensity of pesticide accumulation and duration of their presence (conservation) in the tubers; to suggest biological methods of potato plant protection for reduction of pesticide

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burden in the culture production, which allow producing organic products.

- To determine optimal fertilizer doses enabling to reduce the nitrate accumulation in tubers next lower order of the Threshold Limit Value (TLV) approved for child care and health care centers.
- To determine the heavy metal contamination level of potato tubers growing in the vicinity of 'Don' (M-4), the major federal highway; to evaluate its impact on nitrate accumulation in plants; to substantiate inadmissibility of organic potato field placement nearby the major man-impacted areas.
- Following the investigation results to give recommendations for planting ecologically pure food potato for baby and dietary nutrition completely deprived of chemical pesticides and heavy metals and with nitrate concentration being TLV next lower order.

2. Literature Review

The concept 'quality of potatoes' is often treated very simplified, this term being understood as the content of starch, protein, vitamin C, which, according to A. V. Korshunov⁸, is wrong, as the quality of food product is determined by its biological value, i.e. its effect on human and animal life-sustaining activity.

Among the main factors deteriorating the environmental quality of crop products, including potatoes, special attention is drawn to the presence of pesticide residues, nitrates, heavy metals in it. Their abundance in the production results in numerous serious diseases, including those of carcinogenic nature. Adverse health effects of pesticides, nitrates, heavy metals are multifaceted, non-specific, having different consequences which include generative properties. Diseases which occur at this are hardly recognized¹. Children are the most hypersensitive to harmful substances excess, significant growth of various diseases is currently observed among this age group, and adults with chronic diseases are also highly susceptible³. If no measures are taken to provide children with high-quality organic food, in the immediate future steadily deteriorating health of the younger generation could threaten national safety². Thus, according to mass media reports, during military conscription doctors reveal several chronic diseases in most young men. Therefore, specifically for this reason, child care and health care centers foremost need organic products, including food potatoes^{8,13} which must be completely deprived of chemical pesticides, heavy metals (lead, cadmium) and other hazardous substances¹⁰.

Chemical pesticides have been applied in agricultural production for decades, providing rapid growth for plants and improving their marketable condition. However, foremost the pesticide is a poison making poisonous effect on the human body. Even minor amounts of pesticides entering the human body with food and water accumulate in it and are not excreted, subsequently causing irreversible changes of health condition¹¹. Child's body is particularly susceptible to the effects of toxic components, so children need special protection from the damage caused by pesticides⁶.

All metals, including those necessary for life, are toxic to any extent when exceeding their level in products¹⁵. However, cadmium, lead, (and other metals at high concentrations) causing cardiovascular, oncological diseases, nasty forms of allergy, embryotropic disorders are most dangerous³.

There is considerable heavy traffic on the large federal highways. This is accompanied by pollutant emissions: combustion products, brake block wear particles and road pavement attrition products. Moreover, the roadside area soil is getting saturated with heavy metals, which settle out depending on the particle size and mass. Larger ones accumulate at a distance of about 5 meters, light ones of a smaller size settle at a distance up to 100 m. The plants in the areas of HM industrial pollution accumulate a lot of nitrates, along with the high content of these elements (Cd, Pb, Cu, Zn). This is connected with the ability of cooper to activate nitrate recovery¹⁴.

Nitrates, which form nitrites in the gastrointestinal tract of the haematotherms and the man, present a significant danger for human and animal health. These are nitrites, as well as secondary amines and nitrosamines that cause diseases in humans and animals due to the methemoglobin formation in blood, which is especially dangerous for children. Nitrosamines and nitrosamids formed with the participation of nitrates have strong carcinogenic, mutagenic and embryotoxic properties^{6,7}.

3. Methodology

Investigations were carried out in field experiments during 2010-2013 at the Educational and Experimental Farm (EEF) of Bunin Elets State University. To determine the negative impact of motor vehicle exhaust emissions on the heavy metal accumulation in potatoes, tubers were collected at other land plots located at a distance of 50, 100, and 500 m away from the M-4 'Don' highway bed.

The soil of the land plot consists of leached chernozem, moderately loamy ground with humus content of 5.4-6 %.

In EEF field experiments the following preparations against Colorado potato beetle were studied: Actara VDG chemical insecticide (Thiamethoxam, 250 g/kg); biological agents - Fitoverm, CE (Aversectin C, 2 g/l); Acarin, CE (Avertin-N, 2 g/l) and Bitoxybacillin, P (BA-1500 EA/mg, titer of at least 20 billion spores/g). Fungicides (fungus killers) Profit Gold and Ridomil Gold and herbicides (weed killers) Remus and Sencor were applied⁵.

Fitoverm is a biological product of the 4th generation which is based on avermectin complex of *Stereptomyces avermitilis* soil fungus; Acarin is an alcoholic extract from the *Stereptomyces avermitilis* soil fungus; Bitoxybacillin P is a bacterial insecticide⁹.

In the field experiment studying the nitrate accumulation in tubers fertilizer doses amounted to $N_{30}P_{60}K_{30}$, $N_{60}P_{90}K_{60}$, $N_{90}P_{135}K_{90}$ and control land plot had no fertilizer. At another land plot (15 km away from the field experiments) that was at 50m away from the M-4 Don highway bed experiments were carried out to study options for the alleged negative impact of man-impacted zones with regard to nitrate accumulation in the tubers, with fertilizer application dosages making $N_{60}P_{90}K_{60}$, $N_{90}P_{135}K_{90}$ and a control land plot without fertilizer. The area of experimental plots was 56 m², 4-fold replication, Nevsky potato variety was grown.

Concentration of HM (lead, cadmium, copper, and zinc) and pesticides in potato tubers was determined in the technological and analytical laboratory of FSBI branch "Rosselkhozsentr for Lipetsk Region" by inversion and voltametric method (GOST R 51301-99). Nitrates were determined in the agrochemical laboratory of Faculty of Agriculture of Bunin Elets State University by the proprietary procedure⁹ with pH-meter-ionomer 'Expert-001' fluid analyzer.

4. Results

Our study showed that in 10 days after potato treatment against Colorado potato beetle with Actara chemical insecticides its amount in the tubers exceeded TLV by 32-50%, 20 days later it decreased to 3.0-4.1 times and amounted to 0.016-0.025 mg/kg with an acceptable level of 0.05 mg/kg. In 27 days the Actara content dropped to

0.0013-0.0014 mg/kg. In the later samples of tubers taken in 35 days after the chemical treatment, this substance was not found.

Biological insecticides Fitoverm and Acarin provided satisfactory protection of potato plants from Colorado potato beetle and contributed to obtaining a heavy crop. The average potato crop in crop years was as follows: 24.1 t/ha with Fitoverm applied 23.1 t/ha with Acarina applied, and 27.6 t/ha with Actara applied – against 9.6 t/ha in the control land plots without treatment. The Bitoxybacillin preparation was not effective enough, yield made 17.8 t/ha.

From herbicides Remus remained in potatoes the longest. When processing plants against pests on June 18, 2012 with herbicide Remus at 50 g/ha, its concentration in the tubers 43 days later, on July 31, was 0.043 mg/kg; on August, 6 – 0.022 mg/kg; on August 17 – 0.003 mg/kg and on 24 August (66 days later) it was not discovered (TLV = 0.25 mg/kg). Sencor (metribuzin) remained in the tubers after land plot treatment up to 55 days.

In the vegetation season potato bedding was also treated by fungicides: Profit Gold and Ridomil Gold at the recommended dosage. In tuber samples selected in 4 days after treatment with Profit Gold a significant excess of the fungicide content as compared to TLV was revealed (0.09 mg/kg versus 0.05 mg/kg TLV). In 10 and 20 days after treatment it was not discovered in tubers.

After treatment with Ridomil Gold its remaining quantity in potato tubers in 4 days made 0.020 mg, being 0.001 mg/kg in 10 days, and it was not discovered in 20 days (TLV = 0.1 mg/kg).

As mentioned above, in addition to the basic run schedule (15 km distance from the test field), to study the negative impact of industrial area on heavy metal accumulation in the tubers we selected potato samples in the inhabited locality, crossed by the M-4 'Don' federal highway, before harvesting at the private land plots, at a distance of 50, 100 and 500m from the highway bed.

Studies have shown that in spite of a very high flow of vehicles on the 'Don' federal highway in 2011 (30-35 thousand vehicles per day) exceedance of lead and cadmium standard levels were not discovered in the tubers. With an acceptable level of TLV – 0.5 mg/kg for lead and 0.03 mg/kg for cadmium - their content in tubers was, respectively, 0.034 and 0.005 mg/kg at a distance of 50m away from the highway bed. Production of potatoes

is not standardized according to copper and zinc, their concentration at such a distance from the road was equal to 0.64 and 3.074 mg/kg. In 2011 at a distance of 100 m away from the highway the lead content in potato tubers decreased to 0.012 mg/kg and cadmium content was reduced down to 0.0014 mg/kg.

In 2012 in connection with the commissioning of a bypass road the flow of vehicles in the village (where the tubers were sampled) decreased significantly. As a result, the content of lead, cadmium, copper and zinc at a distance of 50m away from the road decreased to 0.015; 0.004; 0.411, and 2.297 mg/kg respectively, and at a distance of 100m – down to 0.004; 0.002; 0,236 and 1,960 mg/kg. Lead and cadmium were not discovered in the analyzed samples grown at a distance of 500m away from the road, only individual samples contained small concentrations of copper and zinc.

In our experiments mineral fertilizers at different doses had a significant influence on the yield of tubers on average during the research years (Table 1).

Table 1. Potato yields and nitrate accumulation in the tubers, depending on the doses of mineral fertilizers

Experiment option	Yield, t/ha (2010-2013s)	Nitrate content, mg / kg			
		2010	2011	2012	Average
1. Without fertilizers	14,4	21	29,9	14,3	21,7
2. N ₃₀ P ₆₀ K ₃₀	19,7	36	42,2	20,2	32,8
3. N ₆₀ P ₉₀ K ₆₀	24,7	62	62,4	50,3	58,2
4. N ₉₀ P ₁₃₅ K ₉₀	29,1	123	116	104	114,3

Thus, when fertilizing with N₃₀P₆₀K₃₀ the potato yield made 19.7 t/ha; N₆₀P₉₀K₆₀ - 24.7 t/ha; N₉₀P₁₃₅K₉₀ - 29.1 t/ha, versus 14.4 t/ha at the test field without fertilizers.

However, along with the increased yield at successive increasing of mineral fertilizer dosage the nitrate accumulation increases at the same time. During determination, their content in the raw tubers at the test field (without fertilizers) was 21.7 mg/kg on average over 3 years. At the initial dose of N₃₀P₆₀K₃₀ fertilizer it increased slightly up to 32.8 mg/kg. Though application of N₆₀P₉₀K₆₀, the previously recommended dose for Central Black Earth Region, providing medium yield, resulted in the nitrate content increase to the level of 58.2 mg/kg; however it remained next lower order of the allowable concentrations for potatoes intended for baby and dietary nutrition. A

further increase in dosage of complete fertilizer to the level of N₉₀P₁₃₅K₉₀ enhanced nitrate accumulation in the tubers to 114.3 mg/kg. It should also be noted that in the meteorologically favorable 2012 the nitrate accumulation in tubers for all test options was the lowest in comparison with 2010 and 2011.

Nitrate accumulation in potato tubers in the man-impacted area (50m away from the federal highway bed) was significantly higher in average over 2 years than in samples taken in the field experiments far from the road. Thus, at fertilizing with N₆₀P₉₀K₆₀ it was 75.3 mg/kg, N₉₀P₁₃₅K₉₀ resulted in 151.4 mg/kg of raw tubers. Our data suggest the inadmissibility of planting potatoes in the direct vicinity of the highway bed due to the danger of nitrate accumulation increase in the tubers.

5. Discussion

Analyzing the research results in the man-impacted area, it is fair to assume that potato plants have a complex of protective properties due to which their storing organs (tubers) do not accumulate excessive amounts of heavy metals despite high level of contamination with exhaust gases. However, as we have formulated the problem of producing organic potatoes, which at the time of tuber harvesting must be completely deprived of pesticide residues, heavy metals¹⁰ (rather than environmentally safe products which may contain small concentrations of hazardous substances at allowable standards¹², we consider that planting of food potatoes intended for baby and dietary nutrition should not be located near major highways or other man-impacted areas. In extreme case, in the absence of other land plots, the distance from the highway bed to the potato bedding should considerably exceed 100m: ranging from 300 to 500.

It follows from the obtained data on the pesticide application that their moderately toxic group is fungicides (Profit Gold and Ridomil Gold); they remain in potato tubers for a short time period after treatment, i.e. the time span of 20 days from potato fertilizing to harvesting is sufficient, as recommended earlier.

However, more toxic pesticides: chemical insecticide Actara; herbicides Sencor and Remus, used in our experiments at the recommended dosage and terms, remain in the tubers in small concentrations considerably longer. Thus, Actara residual amounts are not discovered only in 35 days after treatment; this period being 55 days for Sencor and 66 days for Rimus.

Our experiments revealed optimal fertilizer doses for potatoes intended for baby food. In Russia, approved nitrate TLV in potatoes is 80 mg/kg of raw tubers for children and medical institutions and 250 mg/kg for adults¹². According to the World Health Organization (WHO), the maximum harmless daily dose of nitrate to humans at systematic entering their body amounts to 3.65 mg of nitrate per 1 kg of body weight⁷.

In our case in the options with low or moderate doses of fertilizer - $N_{30}P_{60}K_{30}$, $N_{60}P_{90}K_{60}$ – containing nitrates in the tubers in the amount of 32.8-58.2 mg/kg and when 200 g potatoes per day is consumed by a baby weighing 15 kg, his body will obtain 6.6-11.6 mg nitrogen in the form of nitrate. This is far from harmless level since a child's body will consume 0.44 - 0.77 mg of nitrate as per 1kg of the body weight per day. However, we must consider that nitrates can get into the child's body with other products: vegetables, milk, smoked meat products, drinking water, and their number increases as summed up. Therefore, it is necessary to ensure that any product would contain the least amount of nitrates. According to foreign sources, in the developed countries of the EU the maximum allowable concentration of nitrates in potatoes is set at most 3 mg%⁴.

Based on the results of our research and TLV, during cultivation of potatoes for children's and medical nutritional therapy, nitrogen dosage in a complete fertilizer should not exceed 60 kg on primary nutrient basis per 1 hectare under the conditions of Central Black Earth Region.

6. Conclusion

In the Central Black Earth Region of Russia during production of organic potato products intended for children's and dietary nutrition, the nitrogen dosage in complete fertilizers should be limited to range of 30-60 kg/ha of active ingredient at N:P:K ratio on phosphorus basis making at least 1:1.5:1.

To protect potatoes from Colorado beetle biological insecticides such as Fitoverm and Acarin can be successfully used against its larvae of 1st and 2nd age. In hot weather, with a significant increase in the number of pests, extermination process can be carried out by chemical insecticide Actara (as far as possible not to be limited to one spraying during the growing season). At the same time from the processing with Actara to the

potato harvesting there must be at least 35 days, which guarantees the absence of insecticide in the tubers and meets the requirements of technical regulations¹⁰.

In cases of herbicide applications for pests control in potato crop, Sencor and Remus should be used at the beginning of plant development: Sencor before sprouting and Remus at plant height up to 5 cm in the recommended doses, so that the period of time between their application and harvesting took 55 and 66 days, respectively. At the end of this period contact herbicides were not discovered in the analyzed samples of tubers.

In order to get potato clean from heavy metals it should be placed away from major highways and other man-impacted areas.

We were able to fulfill the part of the current research on the development of technological methods of producing food potato clean from pesticides and heavy metals with nitrate content significantly below the TLV for children's and medical institutions. However, in the future, it is advisable to continue working in this direction. We consider it necessary to conduct research on the production of food potatoes for baby and dietary food free of radionuclides and other pollutants. The reason for the question posed is that, after the Chernobyl accident, large areas in the Central Black Earth Region of Russia where potatoes are cultivated along with other crops were contaminated with radionuclides.

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